Design and Testing of a Long Range Tele-Operated Missile System (U)

Mr. George M. Landingham†
Mr. George A. Sanders‡

Missile Research, Development and Engineering Center
U.S. Army Aviation and Missile Command
Redstone Arsenal, Alabama

ABSTRACT

The Missile, Research, Development and Engineering Center, MRDEC, of the U.S. Army Aviation and Missile Command, AMCOM is developing and demonstrating tele-operated missile systems that provide many of the capabilities that the Army has stated it needs. These capabilities include flexible mission planning, improved Identification Friend or Foe, minimum collateral damage, and precision hit. The Multimode Airframe Technology, MAT, program will be completed in December 1999 and will demonstrate in flight testing a 40-km, man-in-the-loop missile system. The demonstration will include a soft launch using an Allison Inc. turbojet as booster that effectively minimizes the launch blast signature and is inherently an insensitive munition. The flight test will demonstrate a variable geometry airframe and the capability to fly out at high speed, rapidly slow down to a much slower search velocity, and then re-boost in the end game. To reduce risk in the flight test and to test the installed turbojet engine under aerodynamic conditions, a sled will be conducted at Holloman AFB, NM in November 1998. This paper provides details of the demonstration, missile design, sled test and flight test plan . The military usefulness of the missile system is also discussed.

ABBREVIATIONS

AFB	Air Force Base
AMCOM	U.S. Army Aviation and Missile Command
BAT	Brilliant Anti-Tank
BEWSS	Battlefield Enviroment Weapons System Simulation
HIF	Hardware Integration Facility
HMMWV	Highly Maneuverable Manned Wheeled Vehicle
FOG-M	Fiber Optically Guided Missile
JPSD	Joint Precision Strike Demonstration
LCU	Launcher Control Unit
LONGFOG	Long Range Fiber Optically Guided Missile
MAT	Multimode Airframe Technology
MLRS	Multiple Launcher Rocket System
MODSAF	Modular Semi-Automated Force
MRL	Multiple Rocket Launcher
MRDEC	Missile Research, Development and Engineering Center
P^3I	Pre-Planned Product Improvement
R&D	Research and Development
RTTC	Redstone Technical Test Center
SIF	Software Integration Facility

BACKGROUND

Recent experience has demonstrated that the confrontations of the future will likely continue to be operations such as peacekeeping, and small, contained conflicts. Recently, a National Defense Panel, appointed by Congress to critique the Pentagon's Quadrennial Defense Review, released a report that emphasized that DoD must address threats including terrorism and border incursions. Lighter, more agile forces with weapon systems that are characterized by increased automation and long range precision strike were recommended. AMCOM has been a leader in developing man-in-the-loop, tele-operated missile systems that can achieve these goals today, not in the distant future. The Multimode Airframe Technology program is the latest in-house technical demonstration of this technology in a missile capable of extended ranges. Demonstrated was 40-km capability,

† MAT Program Manager, AIAA Member

‡ MAT Deputy Program Manager

with airframe and sub-component designs that can be readily extended to at least 75-km. The airframe developed under the MAT program is referred to as LONGFOG for Long Range Fiber Optic Guided Missile. The design of the airframe and the status of the program have been described in previous papers[1,2] presented at the Missiles Sciences Conference and will only be briefly described here.

The airframe has unique features for a tactical missile that were designed to make the missile as mission-flexible as possible. The missile is launched using only the thrust provided by the turbojet engine that provides approximately 1-g of acceleration. Control of the missile during this soft launch is made possible by embeding the control fins in the exhaust plume. The engine exhaust provides control equivalent to the aerodynamic control produced when the missile is at a flight speed of 100 m/s. The airframe is designed to fly-out at high speed without the drag of the wings that can be kept stored in the fuselage. The missile slows to less than 100 m/s to allow the man-in-the-loop gunner to search for targets. Lift is maintained by deploying the wings in a bi-plane configuration with flaps deployed on the top wing. In the target attack phase, equal maneuverability in both pitch and yaw is achieved by transitioning the wing to an "X" or cruciform configuration. The missile can reaccelerate at a level flight 2.25-g to regain the high speed required to attack air vehicles. The three airframe modes are depicted in Figure 1. The artist conception in Figure 2 depicts the different aspects of a LONGFOG mission. Following terrain features, a LONGFOG is shown exiting a mountain pass at low altitude, searching for a target at slow speed in the bi-plane configuration and attacking a target in the skid-to-turn cruciform configuration.

The ability to payout fiber to ranges in excess of 40-km using the bobbin designed under the MAT program was demonstrated in September 1996 at Eglin AFB, FL. The fiber bobbin was mounted under the wing of an F-16 aircraft in a standard wing pod as shown in Figure 3. The F-16 took off with the fiber attached to a ground receiver and successfully flew a typical LONGFOG mission at a flight speed of 550-ft/sec. In October 1996, the Allison turbojet engine was mated with a LONGFOG airframe and successful remote starting and operation was demonstrated in a short sled test, Figure 4, at Redstone Arsenal, AL.

MILITARY UTILITY

The LONGFOG missile has not been extensively played in deep battle wargames. Certainly not to the extent and technical fidelity that is required to determine critical design parameters such as time to target, warhead size and type, and the need for low observability. The system was played in the Joint Precision Strike Demonstration in 1995. This war game exercise featured a scenario based on Korea. The North Koreans have Multiple Rocket Launchers, MRLs, which are loaded and housed in tunnels in the side of the mountains and could emerge to fire rockets toward the South. Catching the MRL outside the tunnel and scoring a direct kill before it can retreat inside is a mission well suited to the LONGFOG. The gunner can easily identify the target since the MRL would be uncovered on the roadway.

The LONGFOG missile was modeled as HMMWV mounted. To ensure that this was feasible, a HMMWV version was sized and conceptualized as shown in Figure 5. In the current airframe, the missile would overhang the HMMWV during transit. The missile could either be fired from the transit position or elevated to vertical depending on the surroundings. As the figure indicates, the ability to launch in the transit position allows the HMMWV to be in a sheltered position. For the JPSD exercise, a LONGFOG company was postulated consisting of three platoons with three sections with three HMMWVs. The HMMWV version was conceptualized to have four LONGFOGs for a total of 108 missiles deployed 90-km from the target area. The LONGFOG was played in days 5 and 6 of the battle to great success. The missile was called in for high value targets such as the MRLs. If the missile entered the target area and no target was within the field of view, the missile was commanded to go into a rising spiral. On Day 5, the LONGFOG platoons fired 84 total shots with 49 kills. The no kills were due to computer network problems and not due to missile capability. On Day 6, 42 LONGFOGs were fired with 41 kills.

This exercise, while in the end successful, was also a lesson learned about playing R&D systems in formal military exercises of this nature. Other future systems were played in the exercise, but these were systems such as P^3I BAT and Extended Range MLRS that already have a user and a doctrine. The lack of doctrine and a user resulted in considerable difficulty in devising not only a deployment strategy, but in issuing calls for fire. Many of these issues were cleared on the spot by dedicated government employees and support contractors. In addition, the cost to the program in developing the MODSAF models, providing computer assets, and the travel for personnel was prohibitive for follow on efforts. This kind of exercise provides visibility to the user community but does not provide useful data for making engineering decisions. For that, a wargame that allows multiple runs of the same scenario with parametric changes to the missile performance and deployment is required.

At the MRDEC, a wargame called BEWSS, for Battlefield Environmental Weapons System Simulation, was developed to support the fiber optic guided missile development. BEWSS incorporates high fidelity six-degree-of-freedom models of systems under study so that performance parameters can be varied to determine effect. The program allows for "dirty battlefield", countermeasures, command and control, and targeting sensors. A real gunner can be inserted into the simulation at a virtual FOG-M gunner's station. LONGFOG was not modeled per se in BEWSS because the battlefield size is currently limited to less than the 100+-km required for LONGFOG. However, a 30-km, turbojet powered, version of a fiber optic guided missile was modeled and played in the scenario depicted in Figure 6. The scenario was run without a fiber optic guided missile, with a 15-km fiber optic guided missile and with a 30-km fiber optic guided missile. The loss exchange ratio was used as a figure of merit with the results shown in Table 1. The results are quite dramatic. Much of the five-fold increase in loss exchange ratio that results from 15-km to 30 km was realized because of the reconnoiter capability of the fiber optic guided missile that could report additional targets as it flew to an assigned area.

Table1. Results of a BEWSS Wargame Examining the Impact of Varying Range of a Fiber Optic Guided Missile.

CASE	LOSS EXCHANGE RATIO
No Fiber Optic Missile System	1.8
15-Km Fiber Optic Missile	4.6
30-Km Improved Fiber Optic Missile	22.0

COMPONENT DEVELOPMENT

Since the two major milestones accomplished at the end of FY96, the MAT program has concentrated on maturing the development of the components for the LONGFOG. To minimize program cost, residual components from the in-house FOG-M and IOE FOG-M programs were used in LONGFOG. Many of the missile subsystems were designed and fabricated by MRDEC engineers and their support contractors. A complete list of the subsystems is shown in Table 2.0.

Systems testing of the power distribution system and the control actuation system with the turbojet engine were conducted in FY97-98. Figures 7 and 8 show the test set-up at the MRDEC Propulsion Directorate.

After bench testing, components were integrated together in a two step procedure. First, all components were interfaced in the Software Integration Facility, SIF. Here hardware and software interfaces were verified. After extensive testing in the SIF, the hardware transitioned to the Hardware Integration Facility, HIF, where the components were run closed-loop with the six-degre-of-freedom simulation.

SLED TESTING

As this paper is being written, a sled test was scheduled to occur at Holloman AFB, NM in late November 1998. The sled track at Holloman is 10-miles in length and is adequate to run a full LONGFOG mission profile. The LONGFOG and sled will be propelled down the track by the LONGFOG turbojet engine only. Fiber will be payed out during the run. There is some risk in this since the missile will only be two feet above the track and the fiber could snag. To mitigate risk to the overall test, the missile has been programmed to continue utilizing an on-board autopilot. Critical parameters from the sled test include: (1) fiber entrainment due to turbojet exhaust, (2) base heating due to re-circulation of the exhaust into the fiber bobbin, (3) aft body heating, (4) turbojet stability under aerodynamic conditions, and (5) wing deployment and operation under aerodynamic conditions. Perhaps just as importantly, the sled test provides a realistic test of the missile without risking valuable hardware.

FLIGHT TESTING

Flight testing is now scheduled for December 1998. The test is planned for Eglin AFB as shown in Figure 9. The indicated route with two waypoints is approximately 40-km. A tank or other target will be provided for the gunner, but is considered a secondary objective of the flight test since the seeker and tracker have been used successfully many times in the FOG-M program. To prepare for the flight test, a terrain data base of Eglin was obtained and incorporated into a visual simulation. This visual simulation will be used to train the gunner for the flight.

SUMMARY

The Multimode Airframe Technology Program is concluding with a planned September 1998 sled test and December 1999 flight test. This program has demonstrated the technology required to fly a man-in-the-loop missile paying out fiber cable to a range of 40-km. The program objectives were to investigate the technology required for ranges in excess of 100-km. Critical is the data link subsystem that includes the fiber bobbin and the electronics to digitize and pass video and autopilot data up and down the fiber cable. The electronics have proven to be better than expected and can easily achieve 100-km. A preliminary design for a longer range fiber bobbin and fiber cable has been developed using analytical models. Based on the success of the 40-km payouts already accomplished under MAT, the design is not viewed as high risk.

REFERENCES

1. Auman, L.M., Landingham, G.M, Design of a Long Range Fiber Optically Guided Missile, Presented at the 1994 Missile Sciences Conference, Monterey, Ca., November 1994.

2. Landingham, G.M, Sanders, G. A., Design Challenges of a Long Range Fiber Optical Guided Missile, Presented at the 1996 Missile Sciences Conference, Monterey, Ca., November 1996.

Table 2. LONGFOG Components List

MISSILE HARDWARE	MANUFACTUER	CABELING HARDWARE	MANUFACTUER	GROUND HARDWARE	MANUFACTUER
Seeker*	Southern Research	LCU	MRDEC	Fire Unit	MRDEC
Missile Batteries	Ni-Cads (Non-tactical)	LCU Gunner Station (RS422)	MRDEC	Launch Control Unit + S/W	MRDEC
Pressure Vessel, Bearing Oil	MRDEC	LCU Power Control	MRDEC	Gunner's Console *	MRDEC
Space Frame/Rail Assembly	MRDEC	Launcher Cable	MRDEC	Hard Drive*	
Altimeter, Barometric*	Rosemont	Missile Umbilical	MRDEC	Gunner's Station Computer*	MRDEC
Altimeter Probe	MRDEC	Range Safety	RTTC	EIU	MRDEC
Airborne Electronics Unit	MRDEC	LCU 120 VAC	MRDEC	Video Symbology Generator*	MRDEC
Main Power Supply Board	MRDEC	Missile Load Test Box, MLTB	MRDEC	Programmable Ground Controller*	MRDEC
Relay/Safing Board	MRDEC	MLTB Launcher	MRDEC	Video Distribution Unit*	MRDEC
Wing Controller Board	MRDEC	MLTB Umbilical	MRDEC	Power Distribution Unit*	MRDEC
Electronics Interface Board	MRDEC	MLTB Power Control	MRDEC	Autotracker*	TI
FO Transceiver Board	MRDEC	Missile Safety	MRDEC	Missile Load Test Box	MRDEC
CAS Board	MRDEC	MLTB 120 VAC	MRDEC	PLGR*	Rockwell Collins
Missile Computer S/W	MRDEC	Launcher Dist. Box Cabeling	MRDEC	Launcher/Launcher Assembly	MRDEC (Non-tactical)
Missile Computer Board	MRDEC	Crank Air Control	MRDEC	Holdback Mechanism	MRDEC
Auxiliary Power Supply Board	MRDEC	Crank Air Disconnect	MRDEC	Rail Assembly	MRDEC
AEU Housing	MRDEC	Umbilical Disconnect Interface	MRDEC	Launch Rail QE Adjustment Mech.	MRDEC
Telemetry & FTS**	RTTC	Holdback Mech. Interface	MRDEC	Rail to Missile Interface	MRDEC
TM Exercise Port**	RTTC	MAPS	Honeywell	Crank Air Disconnect	MRDEC
TM Harness**	RTTC	MAPS Cable	MRDEC	Crank Air Control	MRDEC
Roll Gyro*	Northrop	MAPS 28 VDC	MRDEC	Umbilical Disconnect	MRDEC
INS/GPS Hardware (PMIGITS)	Rockwell Collins	Fire Unit, FU	MRDEC	Launcher Distribution Box	MRDEC
Composite Skin	MRDEC	PLGR Cable*	Rockwell Collins	Launcher Distribution Box	MRDEC
Wing/Flap Assy.	MRDEC	PLGR 28 VDC*	MRDEC		
Wing Deployment Mechanism	MRDEC	DC Power Supply Cable*	MRDEC	GS S/W Upgrade (AP/Nav)	MRDEC
Wiring Harnesses	MRDEC	DC Power Supply 208 VAC*	MRDEC	GS-PLGR Upgrade	Rockwell Collins
Engine	Allison Inc.	Remote SPIB Cable*	MRDEC	TM/FTS Test Box**	RTTC
External Wire Race	MRDEC	Console Umbilical Cable*	MRDEC		
Aft Connector Bulkhead	MRDEC	Instrumentation Van Cable*	MRDEC		
Fuel Tank/Inlet	Aerotech	Instrumentation Van 208 VAC*	MRDEC		
Control Actuation System, CAS	MRDEC				
Fiber Pack/Bobbin	MRDEC				

* Component leveraged from previous program.

** Non-tactical, testing only, component

Figure 1. Three Configurations of the LONGFOG Airframe

Figure 2. Pictorial of LONGFOG Mission Depicting Three Airframe States

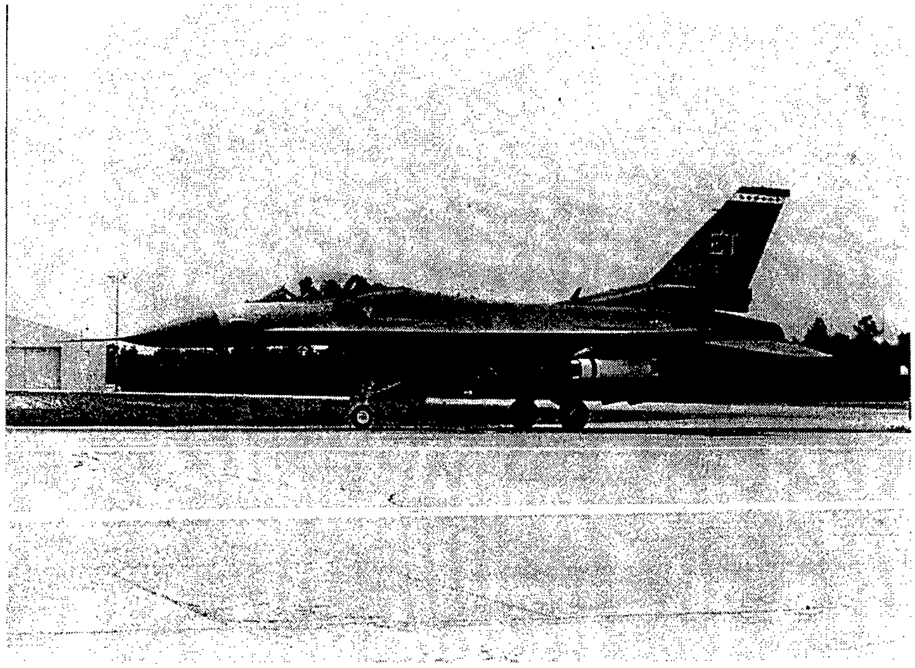

Figure 3. Fiber Optic Cable Payout from F-16 at Missile Flight Speed

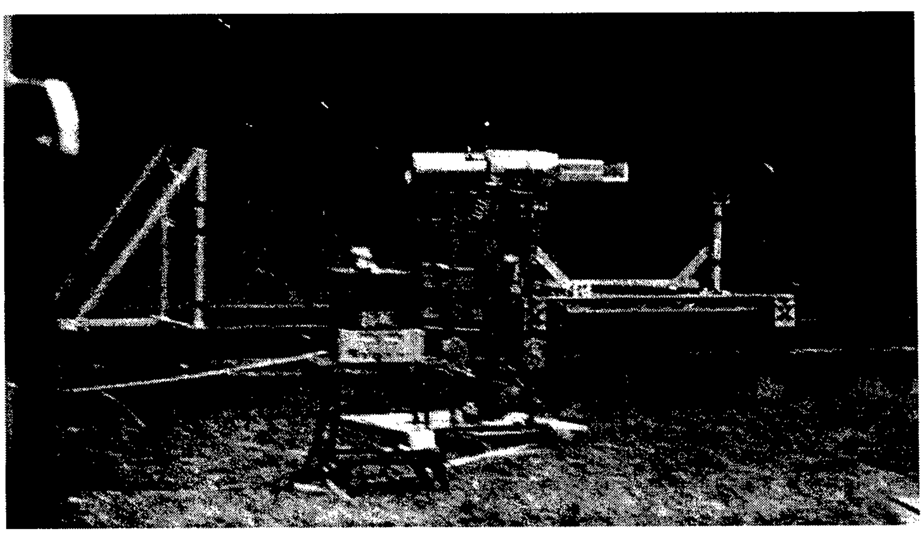

Figure 4. Engine Airframe Integration Demonstration

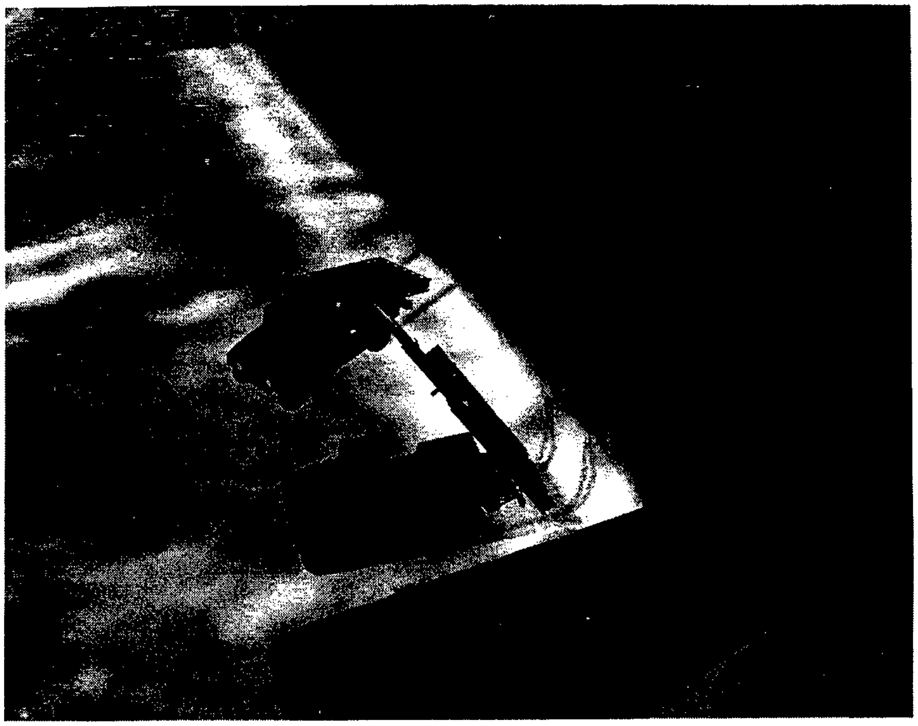

Figure 5. Concept for LONGFOG in a HMMWV Mounted Launcher

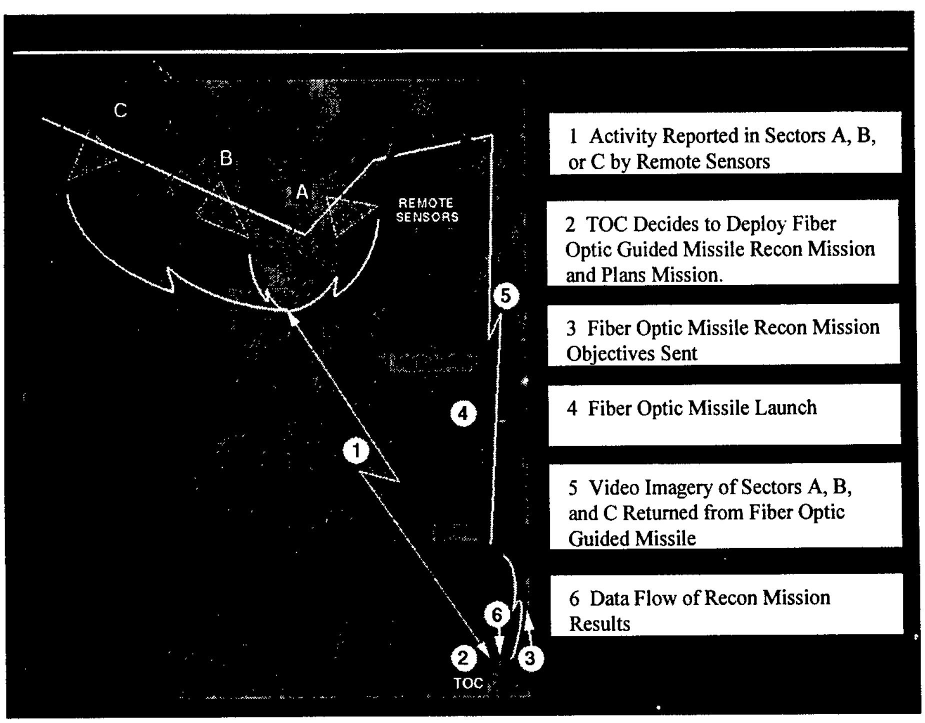

Figure 6. Battlefield Environment Weapons System Simulation Simulation with 30-Km Fiber Optic Missile System

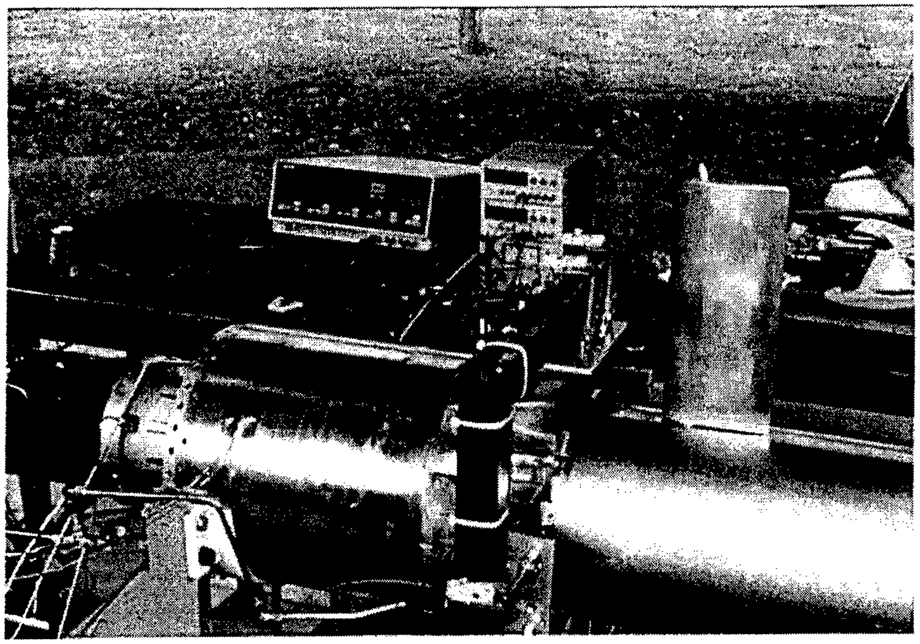

Figure 7. Test Set-up at the MRDEC Propulsion Directorate for fin-in-the-plume testing with flight hardware installed.

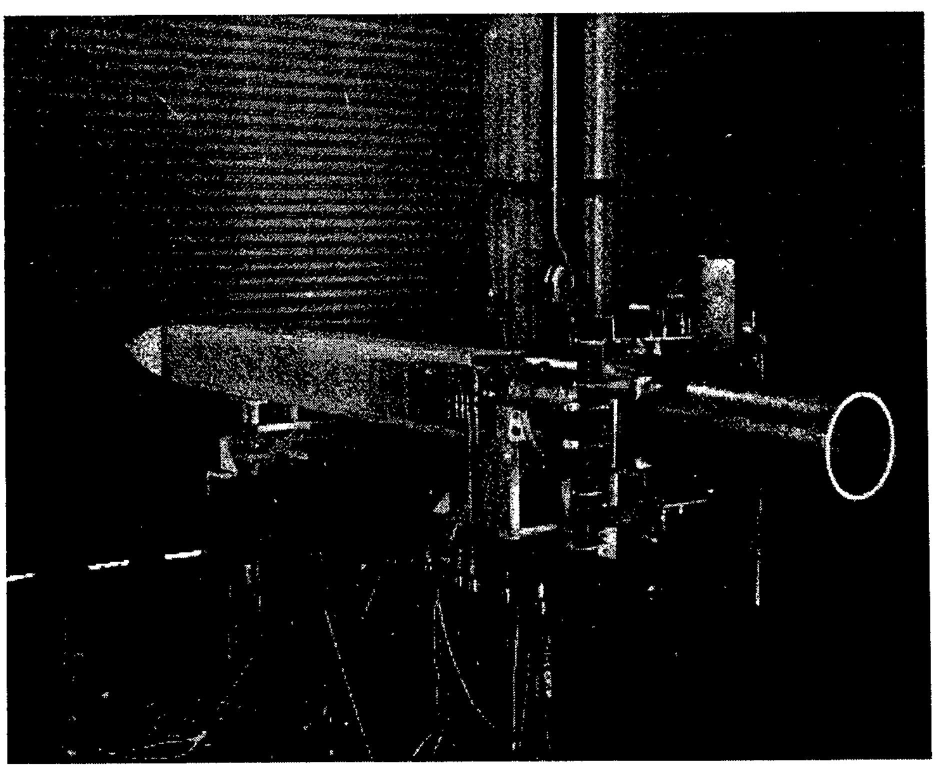

Figure 8. Turbojet Engine Installed in Flight Fuselage

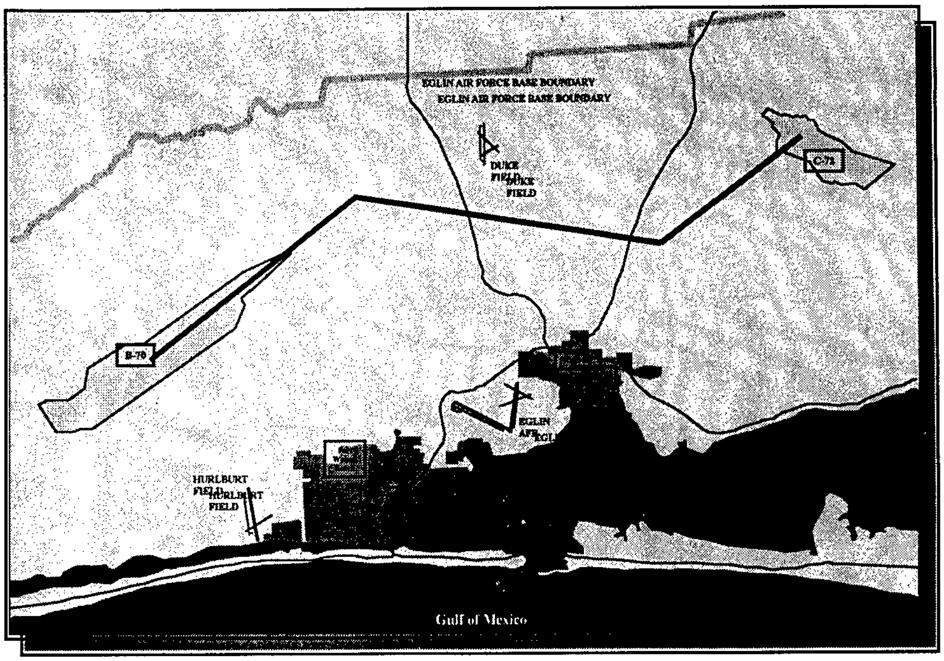

Figure 9. Planned Flight Test Trajectory of 40-km at Eglin AFB, FL.

AIAA 1998 Missile Sciences Conference

Title of Document DESIGN AND TESTING OF A [illegible] LONG RANGE TELE-OPERATED MISSILE SYSTEM.

PLEASE CHECK THE APPROPRIATE BLOCK BELOW:

☐ ______ copies are being forwarded. Indicate whether Statement A, B, C, D, E, F, or X applies.

☒ DISTRIBUTION STATEMENT A:
APPROVED FOR PUBLIC RELEASE: DISTRIBUTION IS UNLIMITED

☐ DISTRIBUTION STATEMENT B:
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES ONLY; (Indicate Reason and Date). OTHER REQUESTS FOR THIS DOCUMENT SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ DISTRIBUTION STATEMENT C:
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES AND THEIR CONTRACTORS; (Indicate Reason and Date). OTHER REQUESTS FOR THIS DOCUMENT SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ DISTRIBUTION STATEMENT D:
DISTRIBUTION AUTHORIZED TO DoD AND U.S. DoD CONTRACTORS ONLY; (Indicate Reason and Date). OTHER REQUESTS SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ DISTRIBUTION STATEMENT E:
DISTRIBUTION AUTHORIZED TO DoD COMPONENTS ONLY; (Indicate Reason and Date). OTHER REQUESTS SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ DISTRIBUTION STATEMENT F:
FURTHER DISSEMINATION ONLY AS DIRECTED BY (Indicate Controlling DoD Office and Date) or HIGHER DoD AUTHORITY.

☐ DISTRIBUTION STATEMENT X:
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES AND PRIVATE INDIVIDUALS OR ENTERPRISES ELIGIBLE TO OBTAIN EXPORT-CONTROLLED TECHNICAL DATA IN ACCORDANCE WITH DoD DIRECTIVE 5230.25, WITHHOLDING OF UNCLASSIFIED TECHNICAL DATA FROM PUBLIC DISCLOSURE, 6 Nov 1984 (Indicate date of determination). CONTROLLING DoD OFFICE IS (Indicate Controlling DoD Office).

☐ This document was previously forwarded to DTIC on ______ (date) and the AD number is ______.

☐ In accordance with provisions of DoD instructions, the document requested is not supplied because:

☐ It will be published at a later date. (Enter approximate date, if known).

☐ Other. (Give Reason)

DoD Directive 5230.24, "Distribution Statements on Technical Documents," 18 Mar 87, contains seven distribution statements, as described briefly above. Technical Documents must be assigned distribution statements.

JESSICA H. JACKSON
Print or Type Name

256-842-9959
Telephone Number

Jessica H. Jackson
Authorized Signature/Date

19981127 032